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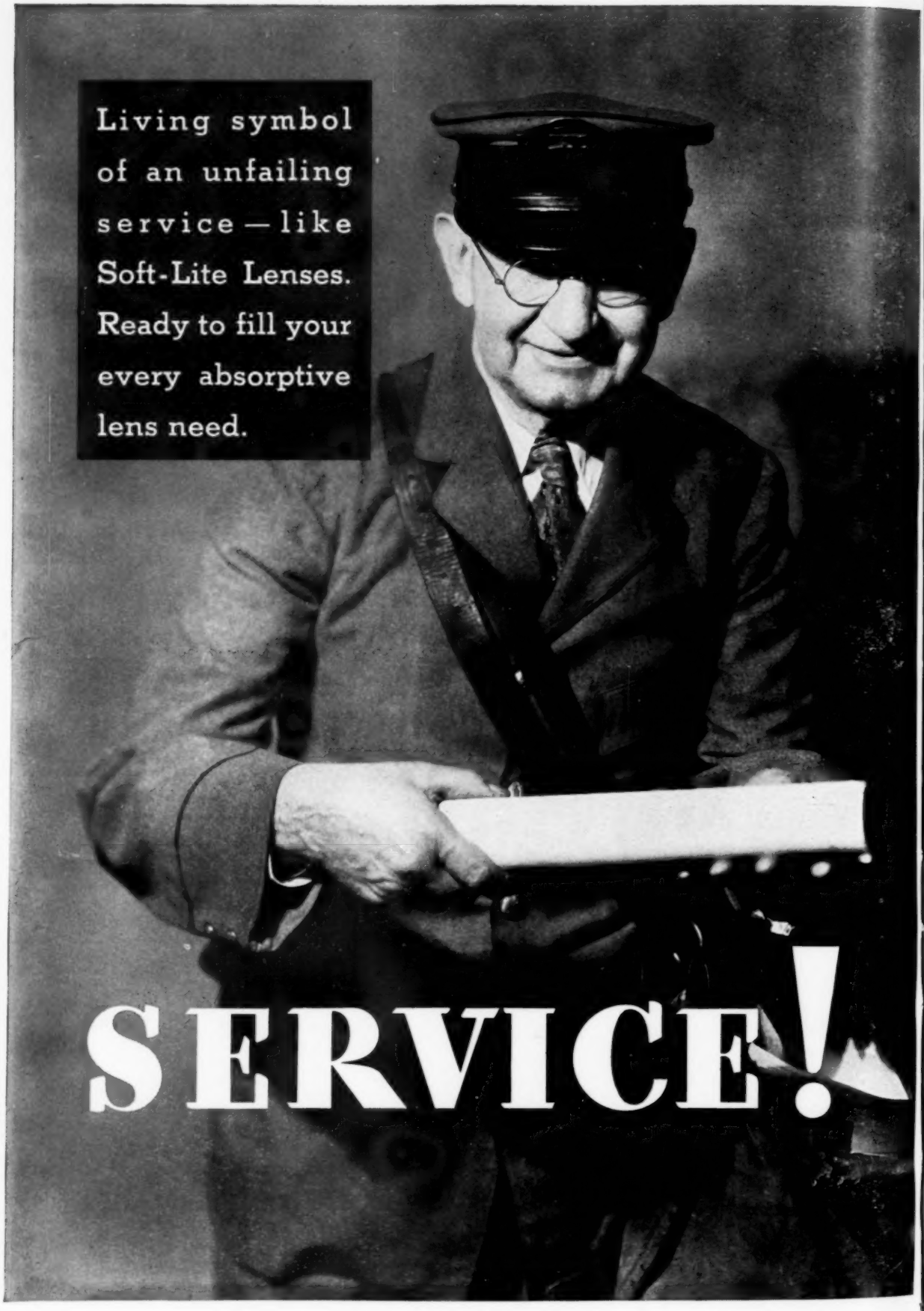
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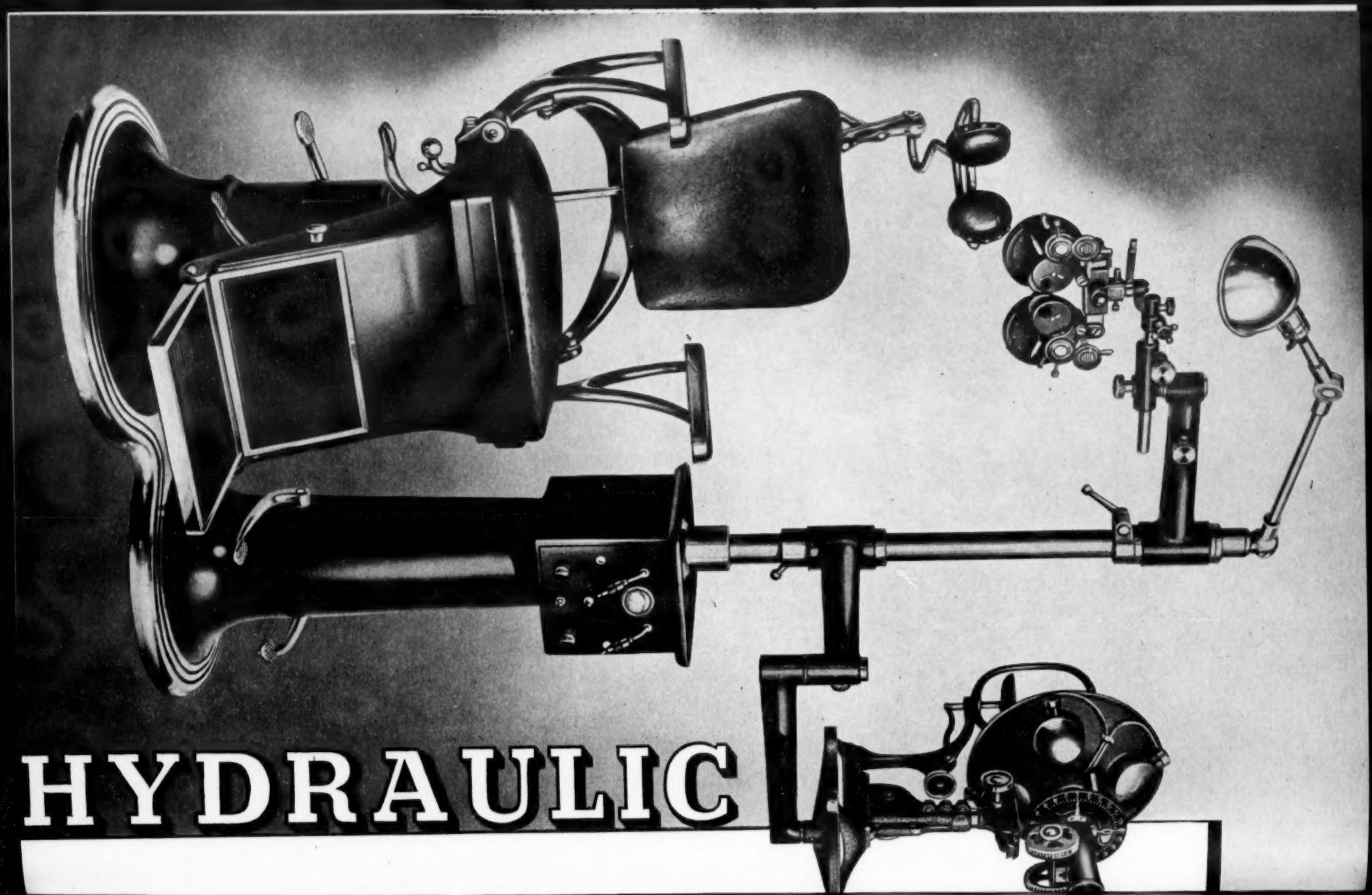

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AMERICAN JOURNAL OF OPTOMETRY

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THE ARGYLL-ROBERTSON PUPIL AND ITS SIGNIFICANCE*

Frederick W. Brock, O.D.
Staten Island, New York

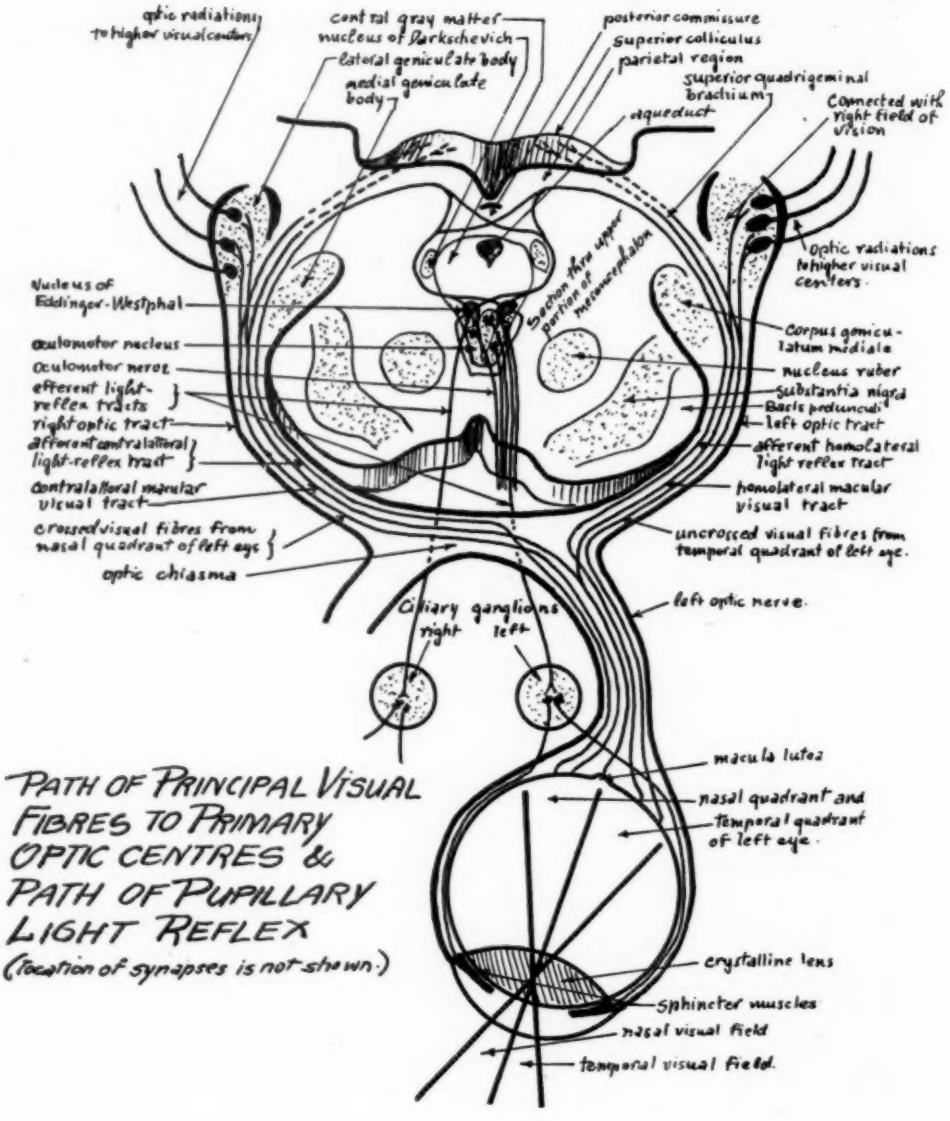
It is a fair assumption that most optometrists know the Argyll-Robertson pupil to be a "dead" pupil, insensitive to light stimuli and usually, but not always, constricted. As a matter of fact the Argyll-Robertson phenomenon is caused by a reflex pupillary paralysis in which vision is retained while there is an absence of the direct and indirect light reflex but with retention of the near-reflex, lid-reflex and psycho-sensory reaction. Diagnosis is of extreme importance because this syndrom is very often indicative of locomotor ataxia. The seriousness of this cerebral disturbance warrants a close study of the pupillary-reflex pathways and a sharp lookout for the sometimes rather obscure objective signs of such a lesion.

A short resume of the pupillary reflexes and their pathways seems in order, particularly so because much of the knowledge regarding those pathways is of very recent origin.

The pupillary light-reflex evidences itself in a direct and consensual pupillary contraction when the retina of an eye receives a certain light stimulus. It seems pretty well established that special pupillary nerve fibres carry the afferent light impulses to the mid-brain. These fibres follow the visual fibres so accurately from the retina, along the optic nerve and the greater part of the optic tract, that their separate entity has been frequently doubted. Even after their presence had been definitely established, little was known of their course except that they became separated from the visual fibres in the last third of the optic tract and that they reached, along conjectured paths, the oculomotor nuclei. Ransom & Magoun[1], in recent laborious experiments finally succeeded, with the aid of the Horsley-Clarke stereo-taxic instrument and application of the most refined technique, in tracing the course of the pupillary reflex fibres of monkeys to the immediate neighborhood of the third nerve nuclei. They have shown, beyond reasonable doubt, that the pupillary reflex paths lead centrad from the optic tract and the superior quadrigeminal

*Submitted for publication June 22, 1935.

brachium to the transition area between the thalmus and the superior colliculus, called the parietal region. From there, the pathway swings ventrally around the rostral central gray matter of the aqueduct to the oculomotor nucleus, undergoing a partial crossing in the posterior commissure and ventral to the central gray matter. Somewhere along the route they synapse.



PATH OF PRINCIPAL VISUAL FIBRES TO PRIMARY OPTIC CENTRES & PATH OF PUPILLARY LIGHT REFLEX
(location of synapses is not shown.)

The efferent route is via the para-sympathetic nerve fibres of the oculomotor nerve to the ciliary ganglion from where the impulses are relayed along the short ciliary nerves to the pupillary constrictor muscles.

The near-reflex (Naheinstellungsreaction) is composed of three synkinetic actions, viz.: accommodation, convergence, and pupillary contraction. The contraction of the ciliary muscle which produces the change of accommodation, the contraction of the sphincter pupillae, and that of the internal rectus which is primarily responsible for convergence, are all dependent upon the third nerve. According to Duke-Elder[2] the ciliary muscle is controlled from a centre in the mid-brain which is presumably in close association with the constrictor centre of the pupil, the efferent pathway being similar to that of the pupillary light reflex. Brouwer's[3] contention, that the centre for convergence is located in the central nucleus of the oculomotor group (Perlia's nucleus), has found almost universal acceptance. It must be remembered, however, that Perlia's is not the only nucleus governing the contractions of the internal recti.

Regarding the lid-reflex, comparatively little seems to be known. Von Graefe[4] apparently was the first to notice that in shutting the lids of one eye the pupil of that eye contracted noticeably, the reflex being entirely unilateral, without any consensual activity in the other pupil. It appears, according to Behr[5] that Von Graefe's reaction is due to a central reflex mechanism, innervation of the orbicularis being, perhaps by way of efferent fibres, derived from the third nucleus.

The psycho-sensory reaction is caused by stimulation of any sensory nerve—with the exception of those supplying the eye itself and its adnexa—and brings about a dilation of the pupils. This reaction follows both physical and psychical (excitement, extreme interest, emotion of fear) stimuli because it is obviously a function of the cerebral cortex. According to Duke-Elder[6] these sensory and psychical reflexes are due to a synchronous stimulation of the sympathetic dilator mechanism[11] and an inhibition of the autonomic constrictor mechanism forming one co-ordinating reflex. Each factor may act alone in the absence of the other.

In the study of the lesion or lesions causing the Argyll-Robertson phenomenon the experiments of Ransom & Magoun[7] prove of great importance. One of the most recent Text Books of Ophthalmology (Duke-Elder, 1934) states regarding the visual and reflex fibres as follows:

"In the posterior third of the optic tract, however, the two sets of fibres separate, the pupillary fibres parting company from the visual: their further course is hypothetical. It is certain that they reach a constrictor centre in the mid-brain in the neighborhood of the third nucleus, and clinical and experimental evidence shows that in their journey thither they are undergoing a decussation. The most probable hypothesis (which, it must be remembered, is only an hypothesis) is that the

fibres travel by way of the superior brachium to the superior colliculus; there they are relayed and thence they travel to the Edinger-Westphal nucleus."

By producing minute lesions directly above the superior colliculi of monkeys Ransom & Magoun[1] established the course of the pupillary-reflex fibres as shown in the following figure, which has been adapted by Brock according to Rasmussen[8], Duke-Elder[9] and Ransom & Magoun[1]. This simplified drawing shows, besides the afferent and efferent paths of the pupillary visual-reflex fibres of one eye, the principal afferent visual fibres from the retina. For the sake of simplicity these are only drawn as far as their primary optic centres with occasional indications as to their connection with the higher optic centres. A cut through the mesencephalon immediately above the superior colliculi and passing through the oculomotor centre enables us to follow the path of the pupillary visual reflex fibres from the retina to the Edinger Westphal nucleus, one of the nuclei of the third nerve in the region of the anterior corpora quadrigeminy below the Sylvian aqueduct. It is placed antero-laterally. From the diagram it may be seen that the reflex fibres not only follow the visual fibres very closely but that, to further increase their similarity, the fibres of the temporal quadrants of each eye remain uncrossed in the chiasma while those of the nasal quadrants decussate and follow a contra-lateral path to the mid-brain. It is only after the visual and reflex fibres have passed through the superior quadrigeminal brachium that the latter take a more elevated position than the former by passing through the parietal region while the visual fibres enter the superior colliculi. This fact[1] and Ransom & Magoun's contention that the reflex fibres partially decussate both in the posterior commissure and ventrally to the central gray matter surrounding the aqueduct is, as can be seen, in direct contradiction to the heretofore almost universally accepted hypothesis, and is, of course, of great diagnostic importance.

If there are two partial decussations in the mid-brain—as shown by the accompanying diagram—it must of necessity follow that a lesion located in the posterior commissure can not create a total bilateral reflex paralysis (Duke-Elder[9]) unless it is of such an extent as to also include the uncrossed fibres of the parietal region. A lesion of such proportions would hardly restrict itself to a reflex paralysis only but, it seems reasonable to assume, would have a much farther reaching effect.

Considering that, according to Duke-Elder[9], supra-nuclear lesions produce ipso-lateral complete paralysis of light–, near–, and lid-reflexes and that, as Hutchinson[10] has shown, lesions affecting the pupillary reflex centre itself or the efferent pathway produce an absolute paralysis wherein the direct and consensual reactions to light, the near reflex, lid reflex, and the psycho-sensory reaction are all abolished, it remains almost conclusive that a lesion producing the Argyll-Robertson syndrom must be located in the direct vicinity of the third nucleus. In

case of a bi-lateral paralysis a central lesion encroaching upon both Edinger Westphal nuclei may well be responsible.

The reason why a lesion in the immediate neighborhood of the third nucleus does not destroy the near and psycho-sensory reflex and presumably the lid-reflex as well can be found in the fact that of the four reflexes involved in the Argyll-Robertson syndrom the pupillary light-reflex, and it alone, has no cortical connection and therefore no supra-nuclear co-ordinating mechanism which probably permits the other stimuli to choose any of several lower paths to subserve their functions.

It is precisely on account of the specific localization of brain lesions causing the Argyll-Robertson symptoms that make their detection so important and the diagnosis so positive. Yet many a "dead" pupil passes the optometrist—and occulist as well—unrecognized or unheeded. This is not always due to a careless attitude of the examiner because, as was stated at the outset of this discourse, a great many Argyll-Robertson pupils are not easily recognized as such, especially if they are of long standing. The main reason is that miosis does not always accompany a reflex paralysis and the anisocoria may be very slight even in a darkened room. The further fact that the Argyll-Robertson syndrom is mostly met with in middle-aged or old people with normally sluggish and reduced pupillary reflexes and that, furthermore, the patient very often focuses alternately a distant target and the flashlight which produces the light stimulus furnishes another reason. This change of focus calls into play the near-reflex and creates a pupillary contraction nearly, if not altogether, equal to that of the light-reflex of the other, unaffected, eye.

The remedy lies of course in a careful examination of the different reflexes. When it is remembered that the light—and near-reflexes are summated, a simultaneous observation of both pupils cannot fail to bring irregularities to light. It must not be supposed that the Argyll-Robertson pupil is too rare a symptom to warrant all this attention. In my own practice, which is probably average, I have met a good many and often the eye examination has been the first indication of the unsound physical condition of the patient.

NOTE—While this article was being prepared for publication, an interesting case of the Argyll-Robertson syndrom presented itself at my office.

J. S. S., age 65, an inmate of Sailors Snug Harbour, Staten Island, came to me with a complaint of double vision. A preliminary examination showed a right hypertropia of approximately 7°, increasing as the eyes were elevated above—and decreasing as they were brought below—the primary position. Fusion was establishd and retained at any point below 25° of the horizontal. A more detailed examination showed a total paralysis of the left superior rectus. Convergence and lateral movements were normal. Accommodation nil. Both pupils were *large* (4 m/m) *and of equal size*. The pupillary light-reflex of the right eye was very feeble, with a normal near-reflex. In the left eye there was no reaction to light whatever but a normal near-reflex. Consensually the right eye reacted almost imperceptively under a strong light stimulus, the

left eye not at all. Visual acuity O.D. —1.00 20/25; O.S. —0.75 20/25. A history of spyhilis contracted in the man's youth completed the picture. The fact that there was an almost complete binocular pupillary reflex paralysis (binocular Argyll-Robertson pupil) with an additional paralysis of the left superior rectus, which has its center of innervation anatomically in very close proximity of the Edinger-Westphal nucleus, showed a considerable lesion in the mid-brain. This was a warning signal not to be disregarded and the man was, of course, immediately referred to the physicians in charge of the Harbour for proper treatment. There was a subsequent report: Wasserman test +4, physical condition too poor to attempt any radical treatment.

What a difference it would have made to this man if his condition had been discovered a few years earlier.

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[9] Duke-Elder: Textbook of Oph h. Vol. 1, p. 550.

[10] Hutchinson: Brain, a Journal of Neurology, London. 1, 155, 458, 1878.

[11] Those readers who would like to inform themselves further regarding the sympathetic pupillary dilator mechanism are urged to read Hammond S. Horton's article on "Ciliary Action & Fatigue" in the American Journal of Optometry, Vol. 10, 272 (August), 1933. I would caution, however, against too ready acceptance of his suggestion that the sympathetic is associated with the mechanism of accommodation. The classical experiments of Langley and Anderson showed too definitely that the sympathetic has no influence on the shape of the lens. (Journal of Phys. IXIII, 554, 1892.)

PRACTICAL MEASUREMENTS OF SIZES AND SHAPES OF OCULAR IMAGES AND THEIR APPLICATIONS*

L. Lester Beacher, O.D., F.A.A.O.
New York City

During the past few years much attention has been given to the subject of "Size and Shape of Ocular Images." Until recently the size differences have been regarded as existing facts, with very little practical significance. Those of us who followed with interest the researches conducted by the Department of Physiological Optics of Dartmouth Medical School, began to realize that the subject is indeed an intricate one.

Previously we assumed that most asthenopia resulted from either a refractive or a fusional disturbance. Ames, Gliddon, Ogle, Madigan and Carlton pointed out that a third factor, the Size and Shape of Ocular Images, can also be a source of disturbance.

In this paper, the speaker presents a suggested technique for office practice. The original principles developed at Dartmouth are used as a basis for the technique. There is no claim made here for originality in theory, but only in applying the theory to our average office practice. Before we can further discuss the subject it will be necessary to differentiate between Retinal Images and Ocular Images.

Sizes and Shapes of Retinal Images depend upon the refractive conditions: i.e., upon the location of the nodal points of the optical system of the eye. They are mathematical.

Sizes and Shapes of Ocular Images, however, depend upon two factors; namely the refractive conditions, and the distribution of the rods and cones. We must bear in mind that ocular images are mental images. They are interpretive elements. They are not mathematical but psychological. They represent images of sizes which the brain interprets, and not sizes the retina receives.

Let us compare two retinae at a given time, both receiving an image of size "Alpha." Then the size of the RETINAL IMAGE of each eye is equivalent to alpha units. Let us suppose, however, that the retinal cells in the right eye are further from each other than in the left eye.

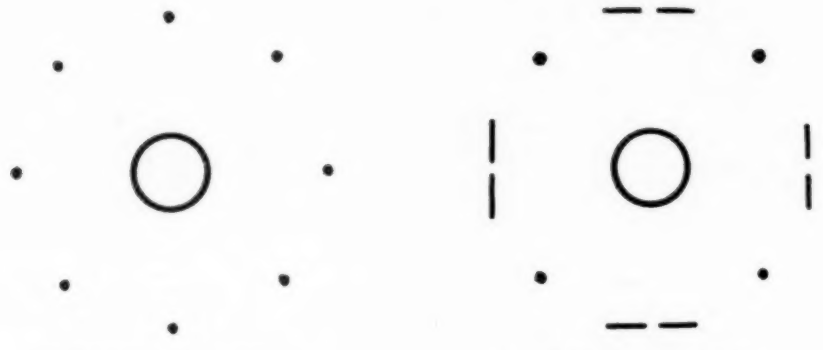
*An abridgment of material presented as part of discussion on Ocular Images, before the American Academy of Optometry at Baltimore, December 18, 1933.

Then the image in the right eye falls on less number of retinal cells than in the left eye. It is logical to conclude that the brain will interpret the right image smaller than the left image. In other words, the ocular image of the right eye is smaller than the ocular image of the left eye, even though the sizes of the retinal images were alike.

In the discussion following, I will confine myself to the consideration of Ocular Images only. At present an accurate instrument is not available for the use of the average practitioner. Hence my interest in this matter has been in attempting to develop a method of making tests with the facilities afforded by the usual office equipment.

As a matter of review we must remember that the theory of the correction of size and shape differences is based on geometrical optics. The positions of the nodal points of optical systems control their magnification. The position of the nodal points can be altered by changing the base curves position and thickness of the lenses, and as a result of such alterations, the size of the projected ocular images can be changed.

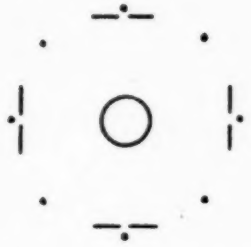
One of the first test charts used in their investigations at Dartmouth is the one shown in Fig. 1. By means of a suitable device the two circles



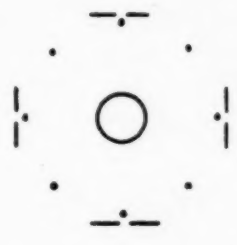
Dr L.Lester Beacher. Fig.1. Similar to the Dartmouth Chart.

were superimposed by the patient (provided there was fusion to start with), while the peripheral dots and lines, being dissimilar images, could not be fused. Each dot was to be seen between the two small lines, provided that the size and shape of ocular images were the same in the two eyes. Differences between the sizes and shapes of ocular images were indicated by the relative positions of the dots and lines. In the latter case all the dots appeared within or outside of the lines, depending

whether the ocular images referred to was smaller or larger than its mate. (Figs. 2 and 3.)



RIGHT IMAGE LARGER THAN LEFT
Dr L.Lester Beacher.Fig.2.



RIGHT IMAGE SMALLER THAN LEFT
Fig.3.

While more efficient methods were later developed, the writer has modified the "Dot and Line" method for use in his office.

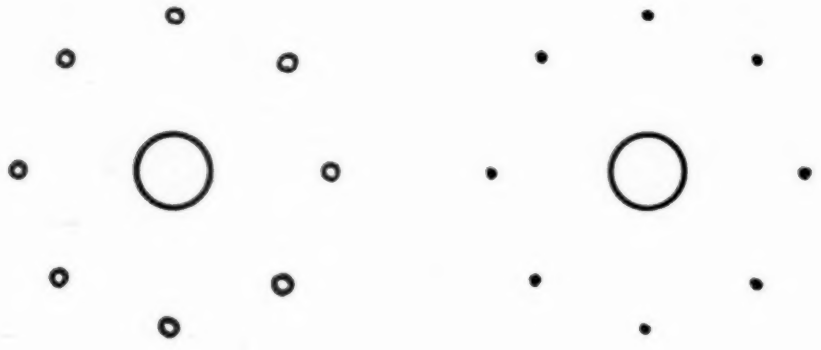
If in this test the presence of fusion is a required factor, then it is logical to use any stereoscope. For this purpose the Dartmouth charts were used in connection with the Keystone Telebinoculator.

Ten individuals were selected to subject themselves to the first experiment. Each one of these fused the central circles and observed the dots in the empty spaces of the broken lines. At the second step, a 2.00 diopter convex spherical lens was placed in front of the right eye. In each one of these ten persons (practically emmetropic and orthophoric) all the dots appeared to be outside of the lines, indicating an overall increased size of the right ocular image. As the third step, a 2.00 diopter concave spherical lens was placed in front of the right eye after the previous convex lens had been removed. Now all the dots appeared to be within the lines, indicating an overall decreased size of the right ocular image. As the fourth and fifth step, a 2.00 diopter convex cylindrical lens at axis 90, and a 2.00 diopter concave cylindrical lens at axis 90, respectively, were used in front of the right eye. With the positive plano cylindrical lens the patients observed the horizontal dots outside of the lines. while the vertical dots were in the empty spaces of the broken lines. With the negative plano cylindrical lens the patients observed the horizontal dots within the lines, the vertical ones being in the empty spaces of the broken lines. In these experiments the changes of sizes of ocular images were induced in one meridian only, effecting a change in the shape of the ocular images.

These results suggested that we are able to, in a measure at least, determine approximately the changes in the size and shapes of ocular images by the use of an ordinary type of stereoscope,it need not be a Keystone Telebinoculator. In fact I have recently replaced it with an American Optical Company Stereophorometer.

Some difficulties were encountered in applying this method with patients. In many cases the patients' problem was to understand what we wanted them to see. Even though another chart was also shown to the patients, showing how the images should appear, many were at a loss.

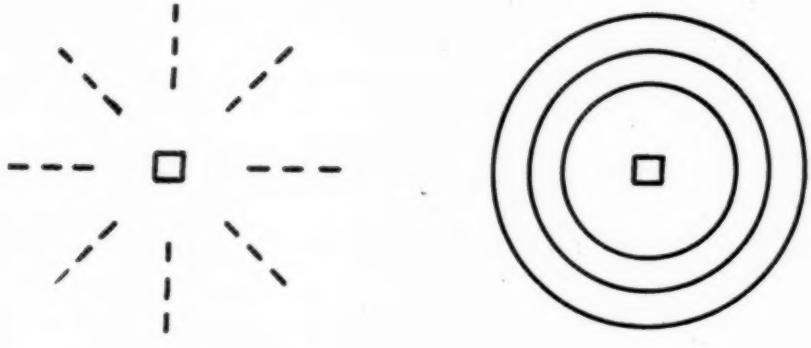
Fig. 4 shows the chart more recently developed, so as to eliminate the previous difficulties. Not as many as before, but still a certain number



LEFT IMAGE RIGHT IMAGE
Dr L.Lester Beacher,Fig.4.

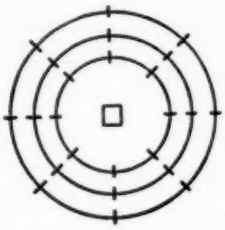
of patients were unable to cooperate. In this chart the patients were to fuse the central circle, and observe the dots in the peripheral circles. Changes of shapes and sizes are observed subjectively. The patient may report that all dots appear on the outer edge of the circles, or on the inner edges, or still further away from them.

While this new chart was more satisfactory than the first one, a third type was designed. (Fig. 5.) If the ocular images of the two eyes

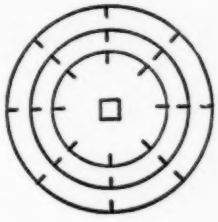


LEFT IMAGE Fig.5. RIGHT IMAGE
Dr L.Lester Beacher

are of the same dimensions, the images will appear as indicated in Fig. 6. With this one, there seems to be less difficulty to obtain the patients' cooperation.



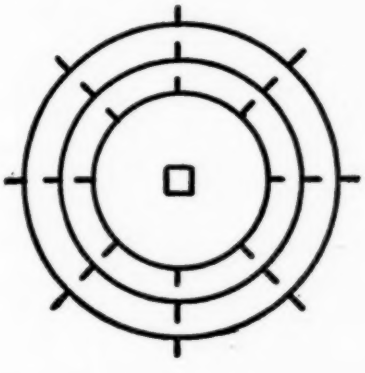
RIGHT IMAGE SAME SIZE AS LEFT
Dr L.Lester Beacher. Fig.6.



RIGHT IMAGE LARGER THAN LEFT
Fig.7.

To date the aforementioned experiments have been carried on with one hundred patients. Eighty per cent showed no size difference. Twenty per cent were anisometropes of over two diopters, each of whom showed size difference without lenses. With the proper correction about one-half of these (11%) showed no size difference, while the others (9%) indicated size difference. By changing the relative base curves the approximate size differences were greatly reduced when again measured with the proper glasses before the patients' eyes.

This brief review has been presented for the purpose of pointing out methods for measuring approximate differences in the sizes and shapes of ocular images, which can be used in any optometric office where there is a stereoscopic instrument. The techniques described in this paper are not quantitative but indicate only the presence or absence of size differences.



RIGHT IMAGE SMALLER THAN LEFT
Dr L.Lester Beacher. Fig.8.

A very simple test occured to me not very long ago. In the short time that I have used it only a few cases have been experimented with. Being that this test is very simple and obvious, I will preface my remarks by citing the advance made because of a simple discovery by the medical profession. It will merely indicate that often a simple matter will prove of great value.

In the olden days surgical interferences were hindered by two handicaps. The first was the shock associated with an operation. The second was the frequent infections which followed most operations. The first one was gradually overcome by various anesthetics offered to the profession. W. T. G. Morton, a well known Massachusetts dentist of the last century discovered ether. Incidently, Dr. John Warren, professor of surgery at Harvard was the first one to try it medically in 1846 when he amputated a leg at the Massachusetts General Hospital.

The second handicap, that of infections, was later reduced by using green soap. Ordinarily we would think that such a simple matter as using soap would be recognized without much thought. Yet someone had to disclose this simple precaution, just a simple idea, after many complicated chemicals failed to give the desired results. Similarly, a simple test which we all use in our practices, can be utilized to interpret size and shape differences of ocular images.

All of us perform a distance and near phoria test. If this is done by means of dissociation of a simple image, the patient can be asked not only whether the images appear underneath each other, but also whether they are both of the same size and shape. This information can be used to roughly approximate base curves of lenses. This test is objectionable from the viewpoint that it is a subjective test. Intelligent patients will report negligible size differences. Less accurate patients will not observe even decidedly noticeable size differences. Like all subjective tests, this should be compared with the other findings. We can foresee the time when size and shap of ocular images will even explain some of the unexplored problems in orthoptics. We must admit that there is still a great deal of untouched field on the subject of strabismus. Perhaps, as problematical as it may seem, some of these facts will be treated from an angle of ocular images. The technique here presented indicates definitely that the fusion faculty cannot overcome certain size differences. It is then logical to conclude that the Size and Shape of Ocular Images will have some bearing in our work on orthoptics. Ames, Gliddon, Ogle, Madigan, and Carlton of the Physiological Optics Research Department of Dartmouth Medical School are to be credited with a great deal of work done on this subject.

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CAUSATIVE AND INTERPRETATIONAL FACTORS IN CORNEAL ASTIGMIA*

George A. MacElree, Jr., O. D.,
and
John F. Morrow, Jr., O. D.

Introduction

At present the Keratometer occupies a unique place in the Optometric armamentarium. Probably no other scientific instrument has been subjected to so much blatant praise on the one hand and such derogatory iconoclasm on the other. Even its name has been a subject of controversy. The gentlemen who invented and modified the instrument, employed the impressive title,—Ophthalmometer—a very evident misnomer. Some optometric practitioners seem to possess a distinct aversion to the usage of the proper and limiting name, Keratometer. Whether this type of reactionary thought has its genesis in a form of hero worship or a blind belief that the instrument really is an ophthalmometer, is not within the scope of this article.

Needless to mention, the authors do not discuss any of the better known variables in this paper. Factors belonging to the optical side of the Keratometer, i. e., the collimation and the focusing errors have been previously investigated and the limits of variance reasonably well established. The variables arising from outside factors such as the effectivity of the correcting lens, physiologic astigmia, etc., have been charted by many investigators, notably Javal, Weiland, and Ryer. Rheostatic control of the illumination is being investigated by the authors at the present time, but no results are available for publication.

For many years, numerous statements have been made concerning the infallibility of the Keratometer; its absolute accuracy as an instrument of refraction and the pure objectiveness of its technique. This is partially due to the instrument's priority in the history of refractive procedures. At the beginning of this century, the Keratometer was advanced far beyond any other means of ascertaining the refractive power of the human eye. Trial lenses and trial frames were in general

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*An abridgement of the material presented before the American Academy of Optometry at Baltimore, Dec. 19, 1933.

usage and even they had not reached the exactness they have today. Naturally the Keratometric reading became the criterion of judgment for all other refractive tests. If static or dynamic skiametry revealed a variation from this standard, the error was inferred to be in the newer technique. The subjective examination, of course, was always regarded as faulty when it dared disagree, for the authority of the Keratometer was beyond reproach.

In the past decade the progress of various other forms of instrumentation has been so rapid and complete that any such discrepancies now appearing are not interpreted as proving the falsity of the newer technique. Most of the minds in the profession at present are unbiased and do not place the blame on either instrument or method without thorough investigation. The Keratometric readings have been subjected to various forms of analysis, such as the Javal rule and its many modifications, Neumueller's tables, etc., but still quite a large number of findings refuse to check with any known method of interpretation. In view of this constant addition of new instruments, and techniques in the optometric routine of refraction, it is obviously unfair to question their truthfulness and assume the veracity of the Keratometer.

The authors, due to their connection with the Clinics of the Pennsylvania State College of Optometry and the resultant vast number of cases that have passed under their supervision, have been kept constantly aware of this situation. A few years ago, they decided to subject Keratometry to a critical examination and to ascertain the trustworthiness and veracity of the instrument in the routine examination. The present paper is in the nature of a preliminary report of the results of their investigations. Research is being continued and some of the problems presented have not been carried to a satisfactory conclusion. It is with the hope that others in the profession will become aware of the significance of these problems and the need for their thorough investigation, that this incomplete report is being made at this time.

PLAN FOR THE PRESENT STUDY

For the sake of clarity it has been thought best to divide this report into the following sections, each being complete in itself:

Part 1. The Index of the Cornea as a Basis for Keratometric Calculations.

Part 2. The Index of the Cornea as a Basis for Astigmatic Calculations.

Part 3. The Variability of the Axis and Axes in the Keratometric Reading.

Part 4. The Variability of the Corneal Curvature.

Bibliographies will be found appended at the conclusion of each part. In some sections, where no reference to previous work could be

found, there is consequently, no bibliography. In most parts, however, the bibliography supplement will be found full and complete. This is due to the authors having had placed at their disposal the very complete files of the Library of the Pennsylvania State College of Optometry.

The presentation of this material in various papers rather than in its entirety will make it much easier for the reader to digest separately each part before proceeding to the next section. As a caution to the reader, may we suggest that the parts be read in their order of publication, for although each is complete in itself as stated, the proper understanding of some of the parts is greatly dependent on work found in the preceding section.

PART I

THE INDEX OF THE CORNEA AS A BASIS FOR KERATOMETRIC CALCULATIONS

History—

The original Keratometer brought forth in 1854 shows small resemblance to the instrument in use today. It actually was nothing more than a modification of one of the forms of the heliometer in use at that time.[1] The methods used were originally employed in the astronomical measurement of small angular distances. This early form had many unfavorable characteristics which made it impractical for clinical or office use. The first practical instrument was brought forward by Laurent whose contribution consisted of providing suitable mountings for the instrument, thus permitting flexibility of adjustment, and the double refracting prism.

Keratometry was really placed in the position of a fixed science and its true importance shown by the investigations of Emile Javal and his pupils in 1880. They developed an instrument which could be used in an ordinary consulting room and which would permit the rapid measurement of the difference between the primary and secondary meridians, as well as measure the radius of curvature and the corresponding dioptric power of the cornea.

To this latter point our attention in this paper is directed. It will be shown that one of the necessary constants employed in the calculations is quite a variable factor. Because of this variability a source of possible error will be demonstrated, which influences not only the dioptric valuation of the cornea, but produces a corresponding error in estimating the corneal astigmia.

A search of the various texts shows a considerable lack of agreement among those considered as authorities. Some of the figures found by the investigators are presented herewith and upon these will be based our calculations. Javal and Schiotz[2] have taken the index of the aqueous (1.3375) and applied this in the calculations to find the

dioptric power for any given radius on the cornea. Under a footnote Tscherning[3] makes this statement concerning the value of this index. "This value of *n*, very nearly correct, was selected in order that, in the following table, 45.00 diopters would correspond exactly to 7.5 m/m., which is convenient in order to regulate the instrument by a sphere type of 7.5 m/m."

The table referred to contains the mathematical calculations for various dioptric values with the above index.

Previously we read that in patients studied by Tscherning,[4] "which I have measured as carefully as possible," the figure of 1.377 is given for the index of the cornea. It will be noted that this figure of his is quite dissimilar to the one used by Javal. It will be demonstrated that this difference produces a higher dioptric value for the cornea and indicates a different amount of corneal astigmia.

Concerning these constants Tscherning[5] has this to say. "We can, therefore, thus measure on the living subject all the optic constants except the indices. But we must not deceive ourselves as to the exactness of these measurements; excepting those of the anterior surface of the cornea, they are not very exact." The reference to the anterior surface probably is in terms of radii, not diopters. Further,[6] he states his experience with the difference between the corneal astigmia indicated and the astigmia found subjectively.

Why Tscherning should agree with Javal for his index, when he had found this index to be different by his own experience, or why he should be dogmatic in affixing a value for the index when he admits the impossibility of measurement, is beyond our powers of ratiocination.

Helmholtz[7] lists the various men who have given a value to this index. These are listed below:

Chossat		1.33
W. Krause	Maximum	1.3569
" "	Minimum	1.3431
" "	Mean	1.3507

Helmholtz does not list a value of his own but assumes the index of the aqueous, and this index as given in his table of indices[8] is 1.3365.

Krause[9] measured the index in a calf's eye enucleated immediately after death and found the index to be 1.3467. The same experiment was performed twenty-four hours later and showed a slight increase; the index then being 1.3480.

Concerning the indices, Helmholtz[10] has this to say, "Measurements of the indices of refraction of the transparent media of the human eye were made many years ago by Chossat and Brewster, who seem, however, to have examined only a small number of eyes; and quite recently W. Krause has carried out an extensive series of such measurements."

Later we read,[11] W. Krause measured twenty eyes from ten individuals, and found considerable variations in them.[11]

Landolt[12] used the figure 1.3365.

Gullstrand[13] employed the figure 1.37 for an unaccommodated eye.

Goldnamer[14] and Atkinson[15] list 1.333 as the index while Brubaker[16] places it at 1.3365.

Pillsbury[17] states that the index is 1.337 but Lewis[18] lists it at 1.33.

Thorington[19] in his table of indices places the cornea at 1.3333.

Concerning some of these figures Sheard[20] has this to say, "It is quite commonly stated that the index of the cornea is the same as that of the aqueous or water, namely 1.333. Such is not true, for the cornea has an index commonly assigned as 1.3375."

From the above it will be readily seen that various values have been assigned ranging from 1.33 to 1.377. Although this has been taken to be an insignificant difference, it will be demonstrated that such a difference, namely, .044, will produce a possible source of error in the estimated corneal power of about 6.00 diopters. It is also probable that the index will vary for individuals of the same age and for different ages, as do other anatomical structures. This point has never been considered in the estimation of the corneal dioptric power. It is easy to understand that when an instrument is calibrated for an arbitrary index (to indicate the amount of corneal power of a human eye, where the index is not known) there is bound to be some possible error. A specific example may be found in the lens measure. This instrument has been known for its complete exactness. The Keratometer has often been likened to it.[21] What a serious error we would make if we attempted to fix the dioptric power of a given set of lenses, whose index of refraction we did not know. Since the index of the glass is easily ascertained, the lens measure is rather accurate, a position that the Keratometer cannot hold, due to the lack of complete knowledge of the optical constants of the human eye. In the case of the index of glass, the optical index is a known quantity, and if it is unknown the radius given in dioptric curves can be checked against neutralization. Such difference, when calculated with the radius, would show the exact index of the unknown substance. Perhaps this same process of reasoning may be applied to the indicated corneal astigmia and the amount of manifest astigmia found subjectively. If this were the case we would not helplessly wander in search of some logical reason why the two astigmatic amounts do not agree when the error lies in the instrument and not on a physiological basis of compensation, although the latter may be present in some cases as an added complication.

In this regard, we specially wish to emphasize the fact that the so-called physiologic lenticular astigmia is a misnomer. The fact is that we do not know exactly where the astigmia is produced, and hence the lenticular phase must be held in doubt. The term physiologic astigmia is much more exact in this connection.

It will be noted from previous statements that those who have attempted work in this field have assigned numerous values and that very seldom two of the investigators agree either with their own work or that of their contemporaries. It is also apparent that in some cases they have employed the figures found by other investigators in preference to their own cited values.

Procedure

When the radius of a reflecting surface is known, the value in diopters is readily calculated. To find the dioptric reflecting value of the cornea the following formula is applied. This formula is universally employed in computing the dioptric power of a reflecting surface.

$$D = \frac{2}{R} \text{ or } \frac{1}{f}$$

D, representing the dioptric value; R, the radius in millimeters; f, the focal length. As an example, let us assume a radius of 7.5 m/m., we then have

$$D = \frac{2}{7.5}$$

D = 266.666 diopters (the reflecting power of the cornea.)

The preceding formula and its application make possible the calculations necessary to find the dioptric value of a reflecting surface.

When a refracting body is being considered, some changes are necessary in the previous formula. Some consideration must be given to the effect of the index on the dioptric power. Lawrence[22] employs the following equation in his computation:

$$D = \frac{N_2 - N_1}{R}$$

D, representing the dioptric value; N_1, the index of air or the medium of the incident ray; N_2, the index of the refracting body or the medium in which the emergent ray travels.

To determine the refracting power of the cornea, the previous formula is applicable when a radius is known and an index is given. The radius being 7.5 m/m., the assumption of Javal, and the index of aqueous (1.3375), being applied as the index of the cornea, the corneal dioptric power is readily calculated.

$$D = \frac{1 - 1.3375}{7.5 \text{ m/m.}} \times 1000$$

D = 45.00 corneal dioptric power.

To determine the corresponding refracting power for various indices, the substitution of the proper values in the above formula will give the desired result.

NAME	INDEX	DIOPTERS	NAME	INDEX	DIOPTERS
CHOSSAT	1.33	44.000	SHEARD	1.3375	45.000
LEWIS	1.33	44.000	GULLSTRAND	1.37	49.333
GOLDHAMER	1.333	44.400	TSCHERNING	1.377	50.266
ATKINSON	1.333	44.400	KRAUSE-		
LANDOLT	1.3365	44.866	MAX.	1.3569	47.586
HELMHOLTZ	1.3365	44.866	MIN.	1.3431	45.746
BRUBAKER	1.3365	44.866	MEAN	1.3507	46.760
PILLSBURY	1.337	44.933	POST M.	1.3467	46.226
JAVAL	1.3375	45.000	24 HR. P.M.	1.3480	46.400
RADIUS = 7.50Z.			AVERAGE	1.3469	46.253

Dr Geo.A.Mac Elree and Dr John F.Morrow. Table ONE.

Table I gives some idea of the influence of the various indices on the total dioptric power of the cornea. In very few instances, does one authority agree with another. As a result of this diagreement, great difficulty is encountered if an attempt is made to set a figure that would represent a standard or normal amount. This may be seen readily by examining the two indices that are closest in agreement. A difference of .001 exists in their values. This difference results in a disagreement in the total dioptric value to the extent of .134 diopters. When a comparison is made of the greatest and the lowest possible index, the error becomes more pronounced. In this later case, a difference of .044 in the indices influences the resultant dioptric power to the extent of 6.266 diopters.

A study of Table II will show that if the index is increased or decreased .005, there is a corresponding change in the dioptric power of the cornea to the extent of .667 diopters.

An increase of .05 in the index produces a greater change in the dioptric value; that of 6.22 diopters or a change of 0.1 creates a difference of 13.333 diopters.

A change of .015 in the index produces a 2.00 diopters change in the corneal power when $r = 7.5$.

When the radius is increased by 1 m/m., as in the Table III, and the index subjected to a change of .005 and .05, a difference is noted in the dioptric values to the extent of .588 and 5.882 diopters. In addition, a change of 0.1 produces a change of 11.764.

When a standard radius of 7.5 m/m. is computed with an index that may vary one-tenth and a result obtained that varies 13.33 diopters, the fallacy is readily revealed. An example will assist:

INDEX	DIOPTRIC VALUE	INDEX	DIOPTRIC VALUE
1.300	40.000	1.355	47.333
1.305	40.666	1.360	48.000
1.310	41.333	1.365	48.666
1.315	42.000	1.370	49.333
1.320	42.666	1.375	50.000
1.325	43.333	1.380	50.666
1.330	44.000	1.385	51.333
1.335	44.666	1.390	52.000
1.340	45.333	1.395	52.666
1.345	46.000	1.400	53.333
1.350	46.666	RADIUS = 7.50 M/m.	

Dr Geo.A.Mac Elree and Dr John F.Morrow. Table TWO.

n = 1.30 = r 7.5 m/m. = corneal power 40.00 diopters, and

with n = 1.40 = r 7.5 m/m. = corneal power 53.33 diopters, and

with n = 1.3366 = r 7.5 m/m. = corneal power 44.88 diopters.

The latter figure for the index is employed by one of the popular Keratometers.

The authors realize that in selecting 1.300 and 1.400 as the limits for their tables they are opening themselves to criticism. This was done for the sake of symmetry. We believe, however, that the index does not lie below 1.33, the index of water, or above 1.42, the index of the lens. This gives a span of nearly .1, the same as the tables.

Figure I gives a graphic representation of the variability and readily shows the wide range possible with a constant radius of 7.5 and the index changing only 0.1 from one extreme to the other.

Conclusion

One. There is no established absolute value for the index of the cornea at present. Values given are only arbitrary and range from 1.33 of Chossat to 1.377 of Tscherning.

Two. We have no accurate method of determining the index of the cornea in situ. The present values have been ascertained by mathematical analysis or cadaveric investigation.

Three. The index employed as a basis in the calculations of one

INDEX	DIOPTRIC VALUE	INDEX	DIOPTRIC VALUE
1.300	35.294	1.355	41.764
1.305	35.882	1.360	42.352
1.310	36.470	1.365	42.941
1.315	37.059	1.370	43.529
1.320	37.647	1.375	44.117
1.325	38.235	1.380	44.705
1.330	38.823	1.385	45.294
1.335	39.411	1.390	45.882
1.340	40.000	1.395	46.470
1.345	40.588	1.400	47.058
1.350	41.176	RADIUS = 8.50 m.	

Dr Geo.A.Mac Elree and Dr John F.Morrow. Table THREE.

Keratometer (1.3375) is not based on previous authoritative investigations and is not accepted as accurate by present day authorities.

Four. The dioptric value assigned to the cornea is only as accurate as the index used as a basis for calculation, in one case, 1.3375, in the other, 1.3366.

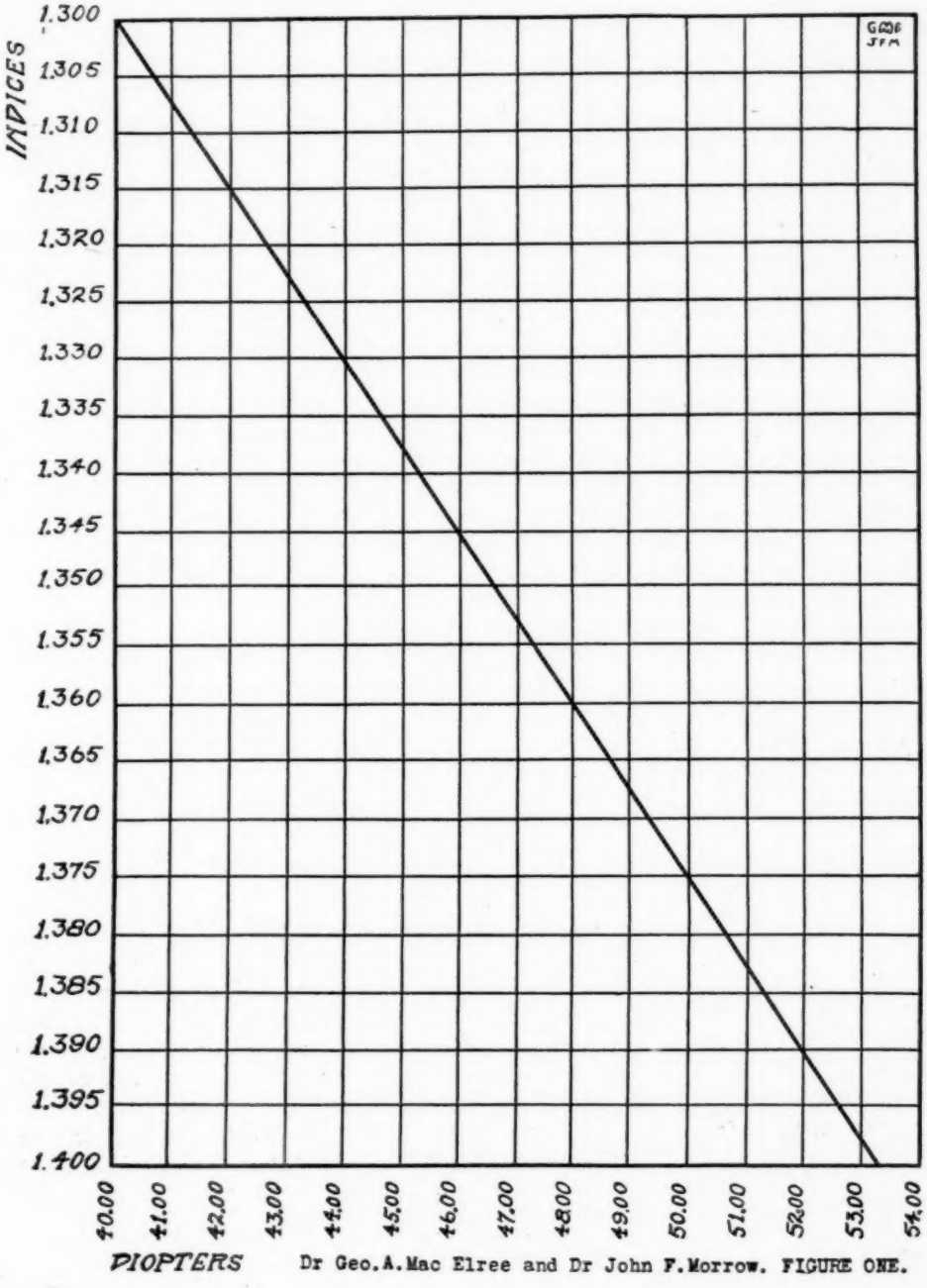
Five. The index may be subject to variability in individuals, and in all probability in the same individuals at different ages.

Six. The Keratometer will give precisely the different radii of the cornea. These radii, when computed against an unknown quantity, such as the index, do not estimate precisely, the corneal dioptric power.

Seven. Increases in the index produce proportionate changes in the corneal dioptric power.

Eight. To estimate correctly the corneal dioptric power, the index should be measured on each individual subject.

Nine. Most Keratometers do not follow one index throughout, they change from 1.3375 at one end of the scale to 1.33 at the other. Needless to say, there is no excuse for this change in index. We have not stressed this concluding point, but anyone wishing to test the accuracy of the particular instrument he possesses, need only apply the refracting formula to the radii values found at each end of the instrument scale and then check the result.



Dr Geo.A.Mac Elree and Dr John F.Morrow. FIGURE ONE.

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PART II

THE INDEX OF THE CORNEA AS A BASIS FOR ASTIGMIC CALCULATIONS

Introduction—

The conclusions stated at the end of Part I lead us to consider the question of the accuracy of the astigmia obtained by the Keratometer. The fact that the index was an unknown quantity did not materially affect the development of the Keratometer. Since it was quite convenient to arbitrarily assume dioptric values for the cornea, and since this was also true for the index, the same procedure was apparently followed in establishing a normal for the radius. Experimental investigations were not conclusive since at no time were more than ten persons used as subjects in determining a constant. That these ten people showed quite variable results was not significant.

If the index of the cornea, on which the Keratometer calulations are based, was only an approximation of the actual value, and the dioptric results seemed to be but arbitrary, it immediately becomes necessary to question the value of the amount of astigmia found, since

the latter depends upon the dioptric values assigned to the two principal meridians.

At this juncture, the authors found they were dealing with an uninvestigated condition. No texts or papers could be found bearing upon this problem. For some bizarre reason, the dioptric power had been criticized frequently, as was shown in the historical summary in Part I, but the verity of the amount of astigmia based on these readings has never been thrown open to question. This can only be accounted for by one of those strange quirks of reasoning that are ever present in various fields of human cerebration. That the index, when calculated with the radius and transposed into diopters, might give misleading results as to the amount of the astigmia present, was probably never discussed. If it has been, the subject has been ignored by contemporary writers and those interested in selling the instrument.

The few individuals to whom the problem was presented were of the opinion that, although the dioptric values of the two principal meridians were in doubt, the astigmic finding would be correct, since the same error would be present in both readings. Just as in using a Skiascope, if the readings revealed a difference of two diopters between meridians, the result would still be accurate as to astigmia even if the axial ametropia were incorrect, since the same amount of error would be introduced in each meridian. The authors' reasoning traveled much along the same channel. Furthermore, we realized that it would be merely a matter of pedantry to question the dioptric value of the Keratometer, if it were perfectly reliable in measurements of the amount of astigmia. If, on the other hand, the index assumed changed not only the dioptric value but the amount of the astigmia, it would become a matter of considerable moment to Optometry.

So, we finally attempted to determine by mathematics, the results in cases of the same difference in radii of curvature and hence the same amount of astigmia, but different indices. Since the Keratometer is depended upon principally for determining the amount of astigmia, if it be proven inaccurate in this respect, it constitutes a serious indictment. The results of our investigations were little short of surprising.

Procedure—

In its primary aspect, the work of this section resembles that of of Part I. The same general formula is used,

$$D = \frac{N_2 - N_1}{r}$$

to obtain the modification for this specific purpose.

$$D = \frac{1000\ (N_2 - 1)}{r}$$

in which D is the dioptric power of the cornea, N_2, the index of the cornea, and r, the radius of the cornea in millimeters.

In this part, the modified formula was utilized in the following manner: An example was used in which the radii in the two principal meridians differed. The formula was then applied to determine the dioptric power of each meridian. These were subtracted and the resulting astigmia noted. This was performed first using N_2 — 1.3375, the index employed in one of the Keratometers. We then performed the same mathematical operation with the same formula but with a different index and compared the two astigmic findings.

A specific example may help to expedite understanding at this juncture. Let us assume the cornea has a radius of curvature of the anterior surface equal to 7.5 m/m. in one meridian and 8.5 m/m. in the other. Astigmia is, of course produced, and its amount must be determined.

In the meridian with a radius of 7.5 m/m., using the index 1.3375, we obtain

$$D = \frac{1000\ (1.3375 - 1)}{7.5} = \frac{337.5}{7.5} = 45.00 \quad (a)$$

or 45.00 diopters of power in this meridian. Using the same method and index on the other meridian with a radius of 8.5 m/m., we have

$$D = \frac{1000\ (1.3375 - 1)}{8.5} = \frac{377.}{8.5} = 39.705 \quad (b)$$

or 39.705 dioptric power in this meridian. Subtracting (b) from (a), we obtain 5.295 diopters as the amount of astigmia.[1]

Then we used the same formula and values for radii but changed the index to 1.377, that found by Tscherning, and ascertained the astigmia

$$D = \frac{1000\ (1.377 - 1)}{7.5} = \frac{377.}{7.5} = 50.266 \quad (c)$$

or the dioptric power of this meridian is 50.266 diopters. Using the same method and index on the other meridian with a radius of 8.5 m/m., we have

$$D = \frac{1000\ (1.377 - 1)}{8.5} = \frac{377.}{8.5} = 44.353 \quad (d)$$

or the dioptric power of this meridian to be 44.353 diopters. Subtracting (d) from (c), we obtain 5.913 diopters or the amount of astigmia for this case.

Now, if a contrast is made of the two cases, we find the amount of astigmia differs to the extent of .618 diopters.

[1]These figures did not correspond exactly to the calibration on one of the Keratometers, which fact was made the subject for another investigation. Surprising enough, we found that the Keratometer that employs the above index has variable index values for different radii.

INDEX	RADIUS 7.5 m/m	RADIUS 8.5 m/m	CORNEAL ASTIGMIA	INCREASE
1.300	40.000	35.294	4.706	0.000
1.310	41.333	36.470	4.863	0.157
1.320	42.666	37.647	5.019	0.313
1.330	44.000	38.823	5.177	0.471
1.340	45.333	40.000	5.333	0.627
1.350	46.666	41.176	5.490	0.784
1.360	48.000	42.352	5.648	0.942
1.370	49.333	43.529	5.804	1.098
1.380	50.666	44.705	5.961	1.255
1.390	52.000	45.882	6.118	1.412
1.400	53.333	47.058	6.275	1.569

Dr Geo.A.Mac Elree and Dr John F.Morrow. Table FOUR.

Results—

From the preceding examples, we notice that a change of 0.0395 in the index, created a possible source of error in the astigmatic finding to the extent of .618 diopter. It was deemed necessary to find exactly the influence of .01 change in the index, on the indicated astigmia. Since the index had been placed at a figure less than water, and since the index could approximate that of glass, these possibilities were included to allow a full span for comparative purposes. The formula employed is the same as the one used in the preceding chapters. That the radius is not apart from this variability will be demonstrated. When a change of .2 m/m. takes place in the radius, the indicated astigmia is in difference, proportional to the error when a 1 m/m. change is effected. This may readily be seen in the following examples of a Keratometric reading when the radii are 6.6 m/m. and 6.8 m/m.:

radius 6.6 m/m.; = 51.00 diopters,
index 1.3366
radius 6.8 m/m.; = 49.50 diopters,

The astigmia amounts to 1.50 diopters.

When the index of Tscherning is employed, we find the values would read:

radius 6.6 m/m.; = 56.04 diopters,
radius 6.8 m/m.; = 54.41 diopters.

In this case, the indicated astigmia amounts to 1.63 diopters. A comparison of the two shows a difference to the extent of .13 diopter.

Table IV contains various dioptric equivalents for the radii employed when the index is increased by .01. It also makes manifest the error in the indicated astigmia with the variable index. It will be noted that as the index is increased by 0.1, the indicated astigmia increases .157 diopters. When the index is increased .1, the astigmia is influenced to the extent of 1.569 diopters.

The table has been constructed so as to consider the extreme possibilities. That this is not necessary to reveal the discrepancy may be seen by a comparison of the figures in the previous example.

If a careful checking of the radii and the dioptric value is performed, it will be observed that on one standard make of Keratometer the index used in the calculation when the radius is 6 m/m. is considerably lower than the figures employed in the other calculations. That this leads to an error in estimating the astigmia may be observed in the following:

Keratometer reads,

radius 6 m/m. = 55.00 diopters

(a)

radius 7.5 m/m. = 45.00 diopters

The astigmia indicated here is 10.00 diopters.
If the astigmia is calculated with the index constant for both meridians as the case should be, the amount of astigmia is different.

radius 6 m/m = 56.25 diopters

(b)

radius 7.5 m/m. = 45.00 diopters

The astigmia amounts in this case to 11.25 diopters.

A comparison between (a) and (b) shows a difference in the total astigmia indicated to the extent of 1.25 diopters.

That the astigmia indicated by the Keratometer is no criterion of the amount actually present, and since it is greatly difficult, if not impossible, to ascertain the corneal index on each individual patient, some means of allowing for the discrepancies is necessary.

It had been demonstrated that an influence of .01 in the index has considerable effect on the indicated astigmia. Now remains to be shown the effects of higher or lower indices on the astigmic findings when such measurement is made by an instrument having a constant index. That such an instrument, when employed on a patient whose index may be lower than that for which the instrument is calibrated, would cause a difference in the subjective findings, is readily seen.

Table V shows the possible allowance that may be made in estimating the corneal astigmia, due to the influence of a variable index.

Some explanation is necessary for a proper understanding of the material in Table V. An attempt has been made to show the influence of the index on the astigmia as indicated by the Keratometer. That the astigmia indicated by the Keratometer is only approximate, has been

INDEX	AMOUNT OF ASTIGMIA				
	1.00	2.00	3.00	4.00	5.00
1.300	-0.12	-0.25	-0.37	-0.50	-0.62
1.3366	0.00	0.00	0.00	0.00	0.00
1.400	+0.25	+0.37	+0.50	+0.62	+0.75
SPAN	0.37	0.62	0.87	1.12	1.37

Dr Geo.A.Mac Elree and Dr John F.Morrow. Table FIVE.

demonstrated. That higher or lower indicies may give different amounts than those shown by the Keratometer has also been demonstrated.

The amount to which this variable index may effect the indicated astigmia is shown in the above table for various values. An example will probably be helpful. When a Keratometer calibrated for an index of 1.3366 indicates a diopter of astigmia, this astigmia is only approximate. Should the index of the cornea of the subject be less than the index for which the instrument is calibrated, the indicated astigmia is in excess to the mount of a .12 diopter for the one diopter of astigmia. In larger amounts of indicated astigmia, the influence of the index is more pronounced.

Conclusions—

One. The astigmia as indicated by the Keratometer is only an approximation of the actual astigmia produced by the anterior corneal surface. The Keratometer will give precisely the values of the radii of the cornea. These radii however, when used in an effort to calculate the corneal astigmia, are not sufficient for the purpose due to the lack of precise knowledge of the corneal index of refraction.

Two. The difference between the dioptric values of the two meridians on the cornea is no indication of the total corneal astigmia present.

Three. To estimate correctly the corneal astigmia, the index of each subject should be measured.

Four. The influence of variations in the index on small amounts under 1.50 of astigmia does not exceed .13 diopter.

Five. The Keratometer is subject to a possible source of error in estimating the corneal astigmia to the extent of from 0 to 2.00 diopters, within the limits of the amounts of corneal astigmia usually encountered.

Six. Subjects having greater index than the one employed by the

Keratometer will accept more cylindrical correction, in the final analysis, than the expected amount.

Seven. The converse of the above is true.

PART III

THE VARIABILITY OF THE AXES IN THE KERATOMETRIC READINGS

Introduction—

A great many practitioners still hold the belief that the primary and secondary meridians of the corneal are usually exactly 90% apart. Ryer (1), however, states that "it was believed for many years that the secondary meridian lay always at right angles to the primary, * * * but the author has proved beyond question that frequently the principal meridians are not at right angles to each other. * * *"

In order to obtain some definite statistical data on the subject, the following investigation was undertaken.

Procedure—

In all the cases examined the Keratometer was reset for axis alignment for each of the principal meridians by the procedure as outlined by Ryer.

This technique consists in focusing the mires sharply, overlapping them two or three steps and turning the axes lines out of the principal meridians, then rotating the telescope so that the secondary meridian was approached and watching for the grayish appearance to pass out and black to take its place. This locates definitely the axis of one of the principal meridians. This method of determining the axes is quite precise and easily carried out. In moving from the first meridian to the secondary meridian, all movements were made in a clockwise direction.

In investigations of this character a trained subject is an absolute necessity and for this reason all of the 100 subjects were members of the student body of the Pennsylvania State College of Optometry.

Results—

A specimen report on 18 cases is given below. Each reading is the result of three distinct observations, checked by three observers.

Table 1 shows the angular difference between the primary and secondary at distance considering the angle that lies between the axis when the Keratometer was rotated in a clockwise direction.

		O.D.	O.S.
1.	J. M.	75.	100.
2.	M. G.	93.	90.
3.	A. G.	65.	75.
4.	L. R.	92.	89.
5.	H. B.	84.	92.
6.	E. W.	83.	87.

7.	C. L.	85.	95.
8.	P. G.	82.	95.
9.	W.	110.	93.
10.	M. W.	80.	91.
11.	A. C.	93.	81.
12.	D. Z.	92.	82.
13.	C. C.	89.	92.
14.	T. D.	111.	80. (A. R.)
15.	J. R.	90.	88.
16.	F. S.	83.	86.
17.	S. M.	80.	85.
18.	M. T.	95.	90.

TABLE VI

All the above cases, with the exception of the one noted, were with the rule type. In a survey of the whole 100 subjects the data was as follows: 38.8 per cent of the cases showed the angle between the primary and secondary meridian to be greater than 90′. The highest angle found was 111′. The average angle for this class being 95′.

In 61.2 per cent of the cases, the angle was less than 90′. The smallest angle being 65′. The average angle for this group being 80′.

It may be noted that the average angular difference for these classes is 15′.

Conclusions—

1. In only a few cases were the axes found to be exactly 90′ apart.
2. The average discrepancy appears to be between 10′ and 15′.
3. Work on several thousand selected cases is necessary, before generalization can be evolved and a general area of distribution determined.

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PART IV

THE VARIABILITY OF THE CORNEAL CURVATURE

Statement—

The work in this particular section is in such an incomplete condition at present, that no report can be given. It might, however, be stated, that some considerable research in literature has been made, in addition to readings taken on about 50 subjects in order to determine the exact limits of corneal variability. The authors firmly believe that once all the variables in a technique are charted and then either abolished or their limitations known, the technique can become an accurate, scientific procedure.

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THE MECHANISM OF ACCOMMODATION

Much has been written upon the subject of accommodation but upon close analysis one finds that many important points still remain unanswered. For instance we still do not know about the relation of the contraction of the ciliary muscle to the increase of the refraction of the lens. With the two theories of accommodation prevailing at the present time, some authorities believe that the contraction of the ciliary muscle causes a contraction of the suspensary ligament of the lens (zonule of Zinn), again others believe that the ciliary contraction produces a relaxation of the suspensory ligaments and that the lens alters its curvature due to its own elasticity. The Helmholtz and Herring theories of accommodation are too well known to the optometrists to require further elaboration, but regardless of which theory one may accept the question which presents itself and still remains unanswered is this: Does it require maximum contraction of the ciliary to produce the maximum amount of accommodation. For instance, does a young person who possesses 12 diopters of accommodation use only a small amount of ciliary contraction in order to increase his refraction by 1.00 or 2.00 diopters, and does a person who has only 1.00 or 2.00 diopters of accommodation have to

use his maximum amount of ciliary contraction to produce this effect? Duane, Clark, Landholt and Donders believe that this is the case, while Fuchs and Hess disagree with them on this point. They contend that the ciliary can always contract more than the maximum amount of accommodation required. Fuchs in discussing this subject differentiates between the "physical" and "physiological" near-point.

The physical near point is the result of the accommodation as limited by a physical condition, such as the flexibility and elasticity of the crystaline lens. This is considered the near point which is normal, the one which recedes with age because of the steadily diminishing elasticity of the lens.

The physiological near point according to Fuchs is that point which could be reached if the accommodation was only limited by the contractibility of the ciliary muscle, a physiological condition. This physiological near point could be reached if the lens was perfectly elastic so that each relaxation of the zonule of Zinn produced by the contraction of the ciliary muscle caused a change in the curvature of the lens and thus increased its refractive power.

Hess suggested that for every diopter increase in refraction there is required an increase in ciliary contraction of the same amount. As a unit of measuring this contraction of the ciliary which is necessary to raise the accommodation from 0 to 1 diopter Professors J. Von der Hoeve and H. J. Flieringo suggest the name "myodiopter" as the unit of measurement. That is if one accommodate 5 diopters he uses 5 "myodiopters" of ciliary contraction. To prove this hypothesis of Hess, Drs. Von der Hoeve and Flieringo conducted some experiments in order to enable them to answer some of these questions:

1. Is maximum ciliary contraction necessary to produce maximum of accommodation?
2. Is the "myodiopter" a constant value?
3. How strong is the power expressed in terms of myodiopters?
4. Is it possible to detect very slight paresis of the ciliary muscle?

They concluded from their experiment that:*

1. The "myodiopter" is a constant value.
2. That it is possible to measure total force of the ciliary in myodiopters.
3. That to produce maximal accommodation maximum ciliary contraction is not necessary.

While this experiment is very interesting and throws some light on the complicated mechanism of accommodation we are still in need for a technique which will enable us to measure accommodation more accurately clinically. That our present clinical methods for measuring accommodation are not very accurate was revealed to the writer recently while

*British Journal of Opthalmology, March, 1924—Page 97-106

carrying out a research problem on the reliability and variability of the near point ocular tests, at the psychology laboratory at the University of Minnesota, the results of which will be published in this Journal in the near future.

We found considerable difference in the accommodation power of the same person at the same time when two different kinds of accommodation tests were used.

When we give this problem serious consideration we must conclude that our accommodative problems are still not solved. Further research is needed to determine the exact accommodative near point, the accommodative time for the normal performance of this function and the retention time, that is, how long one can retain the same amount of accommodative power found at the beginning of the test. The subjective method of bringing the reading card closer to the patient's eyes is not a valid measure of this function. We should try to develop clinical objective methods which will enable us to measure the power of accommodation with a greater degree of accuracy than is possible with our present day technique. J. I. K.

* * * * *

SPECIAL REPORT

OPTOMETRIC INTROSPECTION*

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The almost universal discrimination against optometrists in schools and hospitals, the recent World's Fair Exhibit discrimination and the FERA discrimination would seem to be sufficient reason to justify a little optometric introspection to discover if there exists in optometry any conditions which have invited discrimination or which merit such lack of recognition.

We might take the attitude that such discrimination is the result of the fact that in the field of refraction optometry finds itself in competition with a stronger, more powerful group. Such an explanation might satisfy some, but others believe that we should probe deeper to find a satisfactory solution as to the real cause why optometry finds itself consistently discriminated against in opportunities to participate in public health programs.

Fifteen years ago in Ohio optometry was superior to dentistry in education, yet optometry has failed to achieve the recognition that den-

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tistry enjoyed when her educational status was inferior to that of optometry. At that time Ohio State University gave a four-year course in Applied Optics (optometry). At the same time dentists were being given a doctorate degree in dentistry for a three-year course. The optometric students took practically all the basic science work given to the dentists in addition to the regular work in the theory and practice of optometry. Yet the optometric student failed to receive a doctorate degree—he received only a bachelor's degree. Furthermore, his collge failed to recognize the profession of optometry in that his degree as awarded in Applied Optics. In spite of the superior educational status of optometry at that time in that school, optometry was discriminated against in that optometry students received no doctorate degree and the profession of optometry was not even so much as named in the degree conferred.

Meanwhile the dental profession has continued to enjoy the fullest recognition as a limited practice and has been given an equal place with medicine in all health programs, while optometry with equal consistency has been discriminated against whenever its practioners have sought to make any contribution in a public health program. We should make mention of the fact that in the interim the dental profession has lengthened its course to five and six years' work. These facts seems to indicate that so far as obtaining full recognition for optometry as a profession, high academic standards are essential, but it certainly appears evident that high educational standards alone are not sufficient for attaining the objective.

Higher educational standards are not the entire answer to our problem. Neither do I mean to infer that our present educational status is such that no improvement is advisable. We need a professional curriculum with more basic science and laboratory work of the same quality as is given in universities. We need more courses giving attention to the recognition of the effects of general as well as the presence and effects of local pathology. We need a four-year course preceded by one or perhaps two years' pre-optometric work. We need a doctorate degree which shall be based upon academic credits on par with the academic credits of universities and other professional schools. We might possibly have all these advantages and be no farther ahead than we are today, so far as obtaining recognition for optometry as a profession—because more than education is necessary.

We can organize, we can educate, we can legislate, we can litigate, we can do all these and still fail to achieve the recognition to which we aspire. The simple fact remains that in order to be recognized as a profession optometrists will have to learn to practice optometry as a profession and not as if it were a glorified form of merchandising. To put the issue more plainly, the store practice of optometry must be eliminated *by optometrists* before they can win for optometry the same recognition as a profession which dentistry has achieved. I trust that the fact that I am

practicing in a store and have so practiced for ten years will prevent my views from appearing as colored by prejudice or a "holier than thou" attitude.[1]

The necessity of the elimination of store practice in optometry to me seems necessary for the perpetuation of optometry as a profession. If my thesis be true, we must sooner or later have to face the facts, be they unpleasant or otherwise. Good sense dictates that it is best for us to consider these facts and find a solution if we can.

One frequently hears the remark that an optometrist can practice just as professionally on the ground floor as upon the tenth floor. One may, in a ground floor office, but how can one in a ground floor store? A ground floor office may be in a store room or residence, but in either case the rent will not exceed the rental of an upstairs office in a good office building and there will be no display of glasses in show cases or show windows. Exactness requires that the question be restated, "Can one practice optometry in a ground floor store just as professionally as upon the tenth floor?" That is a question—do we? Personally, I think not. What I may think upon this issue is really of small importance, the consideration which does matter is what the public thinks We will return later to a consideration of the attitude of the public to this problem.

Let us first find out what we optometrists think. Is optometry primarily concerned with the sale of glasses or the examination of the eyes? One must be subordinated to the other. If the examination of the eyes is accepted as the chief service of optometry, then, obviously, in order to practice optometry, we must organize our whole program around the examination. We must give to examination a maximum amount of time with a minimum devoted to dispensing activities and advertising. To place the label of "professional" upon a practice of optometry in which a minimum amount of time is devoted to examination in order to attain a maximum amount of sales of glasses is professional plagarism.

The optometric examination should first and foremost give attention to optometric and medical history and symptoms of eye discomfort which should be followed by sufficient examination and observation to assure that the patient is not the victim of physical disorders, either general or local, which might be responsible for the symptoms either in part or all, *for which glasses might otherwise be prescribed, if these observations had not been made and properly interpreted.* Next, the examination should consist of the purely optometric work of refraction, the determinations of phorias and ductions and the determination of the status of binocular vision. Such an examination requires more time than can be CONSISTENTLY allotted to examination in the ordinary store practice where the overhead is high. In fact, it requires two or three times the

[1]After July 15, 1935, Dr. Morris will be practising in his own office, 201-202 Bass Building, 809 Calhoun St., Fort Wayne, Ind.

usual amount of time which is given to examination in the average "store" type of practice.

The optometrist conducting the average store type practice must make two or three examinations in the same amount of time which would be required to make one examination of the type we recommend, in order to pay the excessive rental and have enough profit left to afford an income equal to that of the upstairs optometrist.

The "store" optometrist can in select cases give the superior type of examination, but the inflexible laws of economics prevent him from consistently giving each patient a superior type of examination.

Is it unreasonable to believe, then, that regardless of our educational status, in spite of all legislation and litigation, we, as a profession, cannot expect the recognition to which we aspire until the majority of optometrists are consistently giving the majority of their patients the most complete eye examination possible? That demands of necessity the elimination of the "store" type practice.

Recognition to which we aspire will have to be achieved in competition with medicine. And in order to defeat the prejudice against us we optometrists will, of necessity, have to be more competent in every detail and give the public a much superior service in order to win out, since we are in competition with a group considerably more powerful than our own group. Survival as an independent profession in competition with medicine demands the elimination of the "store" type of practice.

We pay our respects, as ground floor optometrists, to those courageous souls who seek to blaze the trail by conducting their offices on a strictly professional basis. But unfortunately, other than setting a noble example, their numbers are far too small to affect the situation. We estimate the approximate per cent to be around thirty. Recognition demands a mass movement in large numbers. Optometry must have a large majority professional in order to obtain the coveted recognition.

We believe that a large scale movement toward professionalism is not impossible if we can get our members to see the facts in the right light. It is merely the survival of the most fit. That profession which qualifies first will survive. It is a race between optometry and medicine to see which one will give to the public the best service as a group with regard to conservation of vision through the application of lenses and orthoptic treatments. Do we really want optometry to achieve the status of a recognized profession and share in the public health program alongside of medicine and dentistry? The decision is ours to make, if we will, but first we must examine the facts and think our way through.

The store type of optometrist frequently seeks to defend his position by assuming that optometry can set up standards of professional conduct peculiar to optometry and differing radically from the standards in other professions. In medicine and dentistry the practice of a profes-

sion in a store in connection with the display and sale of merchandise is considered "unprofessional." Now, if we really want to be recognized as "professional" and to participate in the public health work on an equal basis with medicine and dentistry, just how far can we go, if we are going to insist upon our own standards of professional conduct in opposition to those standards which medicine and dentistry have found to meet with the approval of the public?

The contention that the standards of professional conduct adopted by other professions are peculiar to them and that optometry is not obliged to meet these standards is a most fallacious argument. These standards were adopted by the medical and dental professions because they recognized the fundamental needs of the public demanded such standards. Furthermore, the discrimination against optometry seems to us adequate evidence of the disapproval of our special brand of "professionalism" and, conversely, the approval of the standards of our competing profession.

In order to discover whether or not the standards of professional practice in medicine and dentistry were determined by the attitude of the public rather than by the professions themselves, we circulated a questionnaire to some one hundred and fifty students ranging in age from college freshman to mature post-graduate students. Sixty per cent declared that the display of merchandise in show windows or show cases was not in harmony with their conception of what constitutes standard professional practice. Sixty-eight per cent said that one could not practice a profession in a store without sacrificing professional dignity. Eighty per cent said that a professional man should not employ "salesmanship" to sell his consultants services or merchandise.

If this very limited data reflects with any degree of accuracy the opinion of the public as a whole, just what should be the attitude of optometry? Shall we seek to educate the public that their idea is all wrong when applied to optometry or shall we seek to adapt ourselves to what the public expects of us if we claim to be professional men?

What would happen if there would be a large scale movement to higher professional standards? If the majority of ground floor store optometrists were to go upstairs and consistently to give to each patient the most complete type of examination there would be required at least twice as many optometrists to take care of the same number of patients, without any reduction in income to the optometrists or raise in fees to the patient—the difference being accounted for by the demands of the rent of the ground floor stores.

Optometry should be a profession in practice. It is up to us optometrists to decide when we are going to start to practice optometry as a profession instead of a glorified form of optical merchandising.

We are so busy competing with other optometrists that we do not have time to recognize the fact that we are all in competition with another

group—our real competitor—the medical profession. We must eliminate to some degree the "competition idea" in our own ranks and substitute a certain amount of "ECONOMIC COOPERATION." The sound principles of "COOPERATION" have saved the Scandinavian countries from the worst ravages of the depression which has afflicted most countries which have sought to perpetuate themselves on the competitive basis. These principles will work just a well for a group as they will for a nation.

Have we in our numerous optometric organizations leaders who will lead optometry into the paths of economic cooperation and abolish the "store" type of practice by mutual agreement? We do have capable leaders; but we must work out a program if we aspire to make optometry a profession in practice as well as theory.

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BOOK NOTICES

TEXT BOOK OF OPHTHALMOLOGY. Vol. 1 by W. Stewart Duke-Elder. Published by The C. V. Maby Co., St. Louis, Mo. Cloth binding, 1124 pages, 1022 illustrations, 7 color plates, 1934, price $15.00.

The name, Text Book of Ophthalmology does not really do justice to this great work, for it puts the book immediately in a class with most other text books of ophthalmology, which deal with the same subject matter, using the same style, repeating numerous unproven theories, and clinical technique. This book by Duke-Elder is in a class by or Reference of Ocular Science. This name would be more descriptive of itself, there is no other like it. It should have been named a Cyclopedia the contents of this great work, for indeed the many subjects treated in this book and the style used is more of a reference work than a text book.

Many ocular subjects are treated in this book from a scientific, experimental research standpoint rather than from a clinical standpoint. This puts the book in a class by itself and its use is not limited to refractionists only, but it is rather useful to all scientists interested in any branch of visual sciences.

The book is divided into eight sections and 27 chapters. The first three sections deal with the phylogeny of the visual apparatus, the Anatomy and Comparative Anatomy of the Visual apparatus and its ontogenetic development respectively. The fourth, fifth and sixth sec-

tions deal with the physiology and biochemistry of the eye. Optics and the physico-chemistry of Vision. The seventh describes the Physiology of Vision and visual sensation and the eighth, psychology of vision and visual perception.

Many new methods of modern research are discussed and criticised with a skill that can only be expected of that distinguished scientist and research worker Duke-Elder. He not only describes the technique used in the research of a certain problem but he also describes the different instruments and apparatus used as well as the names of the original investigators and the publications where these research reports were originally published.

This Text-Book of Ophthalmology by Duke-Elder contains valuable material of interest not only to the refractionist but also to the physiologist, psychologist who have an interest in any subject related to the visual apparatus.

Duke-Elder did not merely write another book, but he rather furnished a valuable reference work with extensive bibliographies on each subject. It will find a welcome place in the libraries of those who are interested in any phase of the visual mechanism. J. I. K.

EDITORIAL NOTICE TO CONTRIBUTORS

The American Journal of Optometry is a monthly journal, published in annual volumes of about five hundred pages of reading matter each, illustrated where necessary, by cuts in the text.

About four-fifths of the space is devoted to original papers, and the remaining fifth is given over to technical editorials, abstracts and book reviews, *all of them original.*

The papers and reports are original and are accepted only with the understanding that they are to be published in this journal exclusively.

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I. Write on one side of the paper. Double-spaced, typewritten MS. is preferred.

II. Words to be printed in *italics* should be underscored once, in SMALL CAPS twice, and in LARGE CAPITALS three times. **Antique type** when called for should be so marked.

III. Be sure that the title of your paper indicates its contents. Should the subject be a general one, for instance, Case Reports, it would be well to mention the subject of each special report,—for instance: Case One. Progressive Myopia with Exophoria. Case 2. Divergence Squint with Amblyopia. These special titles will appear in the table of contents of each number.

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